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Several models of human motion discrimination have been proposed over the last decade. All are loosely related to the correlator approach originally used by Hassenstein and Reichardt to describe motion discrimination in insect eyes. These correlator models use simple spatial and temporal filtering followed by a non-linear multiplicative operation to account for human direction discrimination of sinusoidal stimuli near contrast threshold. Nevertheless, these models are extremely limited in scope. Research in this laboratory has shown that the correlator models cannot explain human speed discrimination even for sinusoidal targets. Apparently, a higher order network formed by combining local "motion energy units" is required to encode speed. This laboratory has also studied how different features (object components) are combined so that complicated objects move at a uniform velocity. The combination rules are fairly arbitrary, but are limited by physical constraints. Basically, features with similar contrasts, wavelengths, spatial frequencies and temporal frequencies are combined to form a coherent whole moving at a single perceived velocity. Dissimilar features move independently. (AW)

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Research Objectives and Status of Research

Our long-term objective is to create a computational model of human motion processing that explains the basic psychophysical data on direction and speed discrimination. Initially, we thought that a "line-element" model similar to the one used by Wilson for spatial discrimination (hyperacuity) would easily explain human motion discrimination. The components of this model were "motion energy" units -- local spatiotemporal filters that encode target direction and temporal frequency. We assumed that these local motion energy units existed at many spatial scales (many spatial bandwidths) everywhere in the visual field, and that the sensitivity of the units depended on target contrast, spatial frequency and temporal frequency.

While this motion-energy approach can handle the discrimination of direction at contrast threshold, it fails to explain any other aspect of human performance. In particular, it does not explain why velocity discrimination is largely independent of contrast above contrasts of 1%. This type of model cannot even predict human sensitivity to velocity at low contrasts; human observers are substantially more sensitive than this model predicts. A paper describing the inadequacies of this approach is in preparation.

What type of model is needed? The components of the human motion system are probably the local spatiotemporal "motion energy" filters described originally by Adelson and Bergen. What is missing in their model are the rules that describe how these local units are connected. We think these units connected in a network that sums signals along the target trajectory for at least 250 msec -- a second-level that correlated the signals emerging from the first-stage motion energy units. In my laboratory, Sam Bowne and Scott Watamaniuk are using "beat" stimuli to identify the properties of the second stage. Their preliminary results show that this second stage is actually tuned to target speed, not to the temporal frequency of the stimuli used to form the beats. Unlike the "motion energy" stage associated with early visual processing, the second stage is coding space and time, not target spatial frequency and temporal frequency. Moreover, this second stage is largely contrast-independent.

The second-stage trajectory network is hardly adequate to explain all facets of human motion perception. One important question is how does the motion system combine the signals from local detectors to assign a single velocity to a complex object. If the object is formed of features with many orientations, then locally the directions and speeds of each component are different. These signals must be combined to form a coherent percept of a moving rigid object.

In my laboratory, we have used plaid stimuli to explore the computational rules that underlie coherence. A moving plaid is formed by superimposing two moving gratings at different orientations. If the two gratings "cohere", the two gratings appear to move together rigidly as a plaid. If they fail to cohere, the gratings will slide over each other and the observer will perceive motion transparency. Leslie Welch used speed discrimination to show that the existence of two stages in the computation of a single plaid. The limiting noise in the calculation of

plaid velocity was at the neural site that encoded the speed of the component gratings. Nevertheless, if the plaid coheres, the observer does not have direct access to the component signals. Instead the signals for the component gratings can only be known indirectly through the second stage that is responsible for combining the signals. If the gratings do not cohere into a plaid percept, then the observer does have direct access to the component signals. What are the rules governing coherence? Basically, the motion system seems to compare the component gratings on many dimensions to determine whether the gratings are similar enough to belong to the same object. These dimensions include contrast, wavelength, and temporal frequency. Leslie Welch and Samuel Bowne are designing a computational model that incorporates these "coherence" rules.

Professional Staff

Dr. Suzanne P. McKee, Principal Investigator

Dr. Samuel F. Bowne, Unpaid Consultant and Co-investigator

Dr. Dennis M. Levi, Visiting Scientist and Consultant

Leslie Welch, Graduate Student, now advanced to candidacy for the Ph.D. at the University of California at Berkeley; Ph.D. to be awarded this summer

Scott N. J. Watamaniuk, new Postdoctoral Fellow (Rachel C. Atkinson Fellow); former student of Dr. Robert Sekuler; Ph.D. to be awarded in spring.

Douglas G. Taylor, Engineer and Programmer.

Publications

McKee, Suzanne P. & Welch. Leslie (1989) Is there a constancy for velocity? Vision Research, 29 553-561.

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Abstracts

Bowne, Samuel F. (1989) Speed discrimination for sinusoidal targets. ARVO meeting.

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